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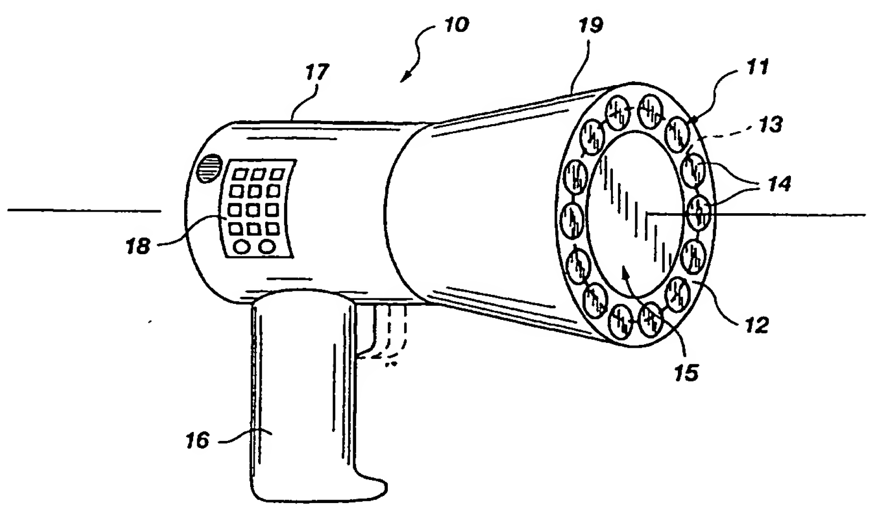
(54) Title: PARAMETRIC RING EMITTER



(57) Abstract

A sound emitting device for providing at least one new sonic or subsonic frequency as a by-product of emitting a waveform of at least two ultrasonic frequencies whose difference in value corresponds to the desired new sonic or subsonic frequency. The device includes a parametric emitting perimeter positioned around a central open section (15). This open section is structured with a diagonal width greater than a cross-sectional diagonal of the parametric emitting perimeter. An ultrasonic frequency signal source (60) and sonic/subsonic frequency generator (62) are coupled together to a modulating circuit (61) for mixing an ultrasonic frequency signal with an electrical signal corresponding to the at least one new sonic or subsonic frequency. The modulator output is coupled to the emitting perimeter (64) which comprises ultrasonic frequency emitting material (14) for propagating the mixed waveform into air for demodulating the waveform to generate the at least one new sonic or subsonic frequency.

PARAMETRIC RING EMITTER

BACKGROUND OF THE INVENTION

This is a continuation-in-part application of copending application, Serial No. 08/846,637, entitled "Light Enhanced Bullhorn", filed April 30, 1997.

1. Field of the Invention

This invention pertains to sound projection devices. More particularly, the present invention relates to a device and method for enhancing a directional parametric speaker while reducing the quantity of ultrasonic emitters required.

2. State of the art

Recent developments have been made involving sound propagation from parametric speakers, acoustic heterodyning, and other forms of modulation of multiple ultrasonic frequencies to generate a new frequency. In theory, sound is developed by the interaction in air (as a nonlinear medium) of two ultrasonic frequencies whose difference in value falls within the audio range. The resulting compression waves are projected within the air as a nonlinear medium.

An interesting property of parametric sound generation is enhanced directionality. Despite significant publications on ideal theory, however, general production of sound for practical applications has alluded the industry for over 100 years. Specifically, a basic parametric or heterodyne speaker has not been developed which can be applied in general applications in a manner such as conventional speaker systems.

A brief explanation of the theoretical parametric speaker array is provided in "Audio spotlight: An application of nonlinear interaction of sound waves to a new type of loudspeaker design" by Yoneyama et al as published in the Journal of Acoustic Society of America, 73(5), May 1983. Although technical components and the theory of sound generation from a difference signal between two interfering ultrasonic frequencies is described, the practical realization of a commercial sound system was apparently unsuccessful. Note that this weakness in the prior art remains despite the assembly of a parametric speaker array consisting of as many as 547 piezoelectric transducers yielding a speaker diameter of 40-50 cm. Virtually all prior

source for generating a first ultrasonic signal, a sonic or subsonic frequency generator for supplying an electrical signal corresponding to the at least one new sonic or subsonic frequency, and a modulating circuit coupled to the ultrasonic frequency signal source and sonic or subsonic frequency generator for mixing the first ultrasonic frequency signal with the electrical signal corresponding to the at least one new sonic frequency to thereby generate a waveform including the first ultrasonic frequency signal and a second ultrasonic frequency signal. The emitting perimeter comprises ultrasonic frequency emitting material which can be coupled to an output of the modulating means for (i) propagating a waveform embodying both the first and second ultrasonic frequency signals, and (ii) generating the at least one new sonic frequency as a by-product of interaction between the first and second ultrasonic frequency signals.

The invention is also represented by a method for enhancing efficiency of a parametric speaker system with respect to energy output based upon emitter surface area, comprising the steps of a) forming an ultrasonic frequency emitting perimeter on a support base around an open region which is substantially void of ultrasonic emitting material; and b) emitting ultrasonic frequency from the emitting perimeter to generate sonic or subsonic sound within surrounding air as part of a parametric speaker system.

Other objects, features and benefits will be apparent to those skilled in the art, based on the following detailed description, in combination with the accompanying drawings.

DESCRIPTION OF THE DRAWINGS

Figure 1 illustrates a perspective view of a bullhorn device incorporating a circular parametric emitting perimeter.

Figure 2 depicts perspective view of a rectangular emitting perimeter utilizing PVDF emitting film.

Figure 3 graphically illustrates an additional embodiment of the present invention incorporating an array of emitter strips to form a polygon configuration.

Figure 4 shows a cross section of the array of figure 3, taken along the lines 4 - 4.

number of ultrasonic transducers or emitter surface area, less drive voltage is required and enhanced efficiency results.

Various forms of emitter devices may be used in this perimeter configuration. Traditionally, parametric speakers have utilized bimorf transducers. The present inventor has developed effective parametric output with PVDF film, as well as electrostatic emitter structures. The selection of material will be a function of desired shape of the support plate, as well as the type of audio range desired. For example, figure 2 illustrates a midrange speaker using piezoelectric or PVDF film 20, a substrate 21 for supporting the film in suspended state above a cavity 22, and a voltage source with attendant audio signal 23. The rectangular configuration is suitable for a film-type emitter because the film can be placed in tension across the opposing sides or diametric edges 24 to provide proper tension in the film. For determining roll off parameters for low range frequencies, the diameter of the speaker is measured along the horizontal axis 25 or vertical axis 26. Normally, the longer diameter (in this example, 25) will control.

The central section 27 is an open portion in the substrate 21 and emitter 20. The horizontal diameter 28 of the opening is approximately twice the distance 30 across a cross-section of the emitting perimeter. This forms a ratio of 0.5 for this orientation. The vertical opening spans a distance 29 which is 5/4ths the distance 30, equivalent to a ratio of approximately .4, a more preferred ratio based on empirical results.

Figures 3 and 4 illustrate a hexagon shape, representative of a general polygon configuration. In this example, electrostatic emitters 32 are supported on a stator substrate 33 over a cavity 34, and are arranged along the respective straight diametric edges 35 of the polygon. Each stator 33 is powered in parallel from a driver 36 which is coupled to an audio signal source (not shown). This embodiment is representative of electrostatic speakers generally, and may include a separate biasing circuit 38, as well as electret materials which can be pre-charged to a desired condition. It will be apparent that virtually any speaker shape can be implemented by segmenting the emitter perimeter into a combination of straight segments and/or curves, and by positioning these in end-to-end orientation to circumscribe an open, central region 40. Such shapes need not be symmetrical, but may be of virtually any

Based on empirical studies, maximum efficiency is realized with a bimorf array as shown in figure 5, wherein the emitting perimeter has an outer radius r_o and an inner radius r_i which falls within the ratio of $r_o - r_i / r_o$ having a value within the numerical range of .1 to 1.0. The preferred efficiency of .3 is produced with a preferred range of .2 to .4. Other emitter configurations and materials will likely vary from these exemplary ranges for the disclosed bimorf array. In general terms, the present invention is characterized in part by the ratio of (i) a difference between the inner radius and the outer radius of the emitting perimeter, to (ii) the outer radius of the emitting perimeter being within a numerical range of 0.1 to 1.0, or within a more preferred numerical range of .2 to .4.

In view of the foregoing relationships, it is apparent that the direction of propagation is a function of both the ring diameter and the space configuration of the internal region. A planar relationship for the emitter materials offers the most efficient system for several reasons. First, this planar configuration requires the least number of emitters to circumscribe the maximum area. Secondly, the planar relationship maximizes the in-phase relationship between each emitter. This is significant, in order to reduce SPL loss from phase cancellation.

Figure 5 also illustrates an additional feature of the present invention wherein the bimorf emitters are spaced from each other to provide a surrounding separation distance from adjacent emitters. Such a concept of spaced positioning appears to offer further economy by reducing the amount of emitter surface within defined rings of specific diameters. In other words, by reducing emitter material with the specific ring configuration, a further reduction in cost is achieved, yet proportional reductions in SPL do not occur. These open segments 55 can be empirically adjusted to optimize the parametric output, while maintaining the desired radial or diametric relationships mentioned above. Generally, the gaps formed by this displacement will range from .5 to 2.0 cm, and more preferably, from .2 to 1.5 cm. This concept is developed further in a continuation in part application filed by the present inventor.

A description of the remaining speaker components will briefly identify operating elements generally necessary to drive a parametric speaker as shown in figure 6. An ultrasonic frequency signal source 60 is coupled to a modulating device 61 for providing a first ultrasonic frequency signal. Typically, this frequency is

CLAIMS

I claim:

1. A sound emitting device for providing at least one new sonic frequency as a by-product of emitting at least two ultrasonic frequencies from an ultrasonic frequency emitter, said device comprised of:

an audio emitting perimeter positioned around a central open section, said open section having a diagonal width greater than a cross-sectional diagonal of the emitting perimeter of the support base, said audio emitting perimeter, said audio emitting perimeter having a directional orientation along a transmission axis;

an ultrasonic frequency signal source for generating a first ultasonic signal;

a sonic or subsonic frequency generator for supplying an electrical signal corresponding to the at least one new sonic or subsonic frequency;

modulating means coupled to the ultrasonic frequency signal source and sonic or subsonic frequency generator for mixing the first ultrasonic frequency signal with the electrical signal corresponding to the at least one new sonic frequency to thereby generate a waveform including the first ultrasonic frequency signal and a second ultrasonic frequency signal;

said emitting perimeter comprising ultrasonic frequency emitting material coupled to an output of the modulating means for (i) propagating a waveform embodying both the first and second ultrasonic frequency signals, and (ii) generating the at least one new sonic frequency as a by-product of interaction between the first and second ultrasonic frequency signals.

2. A device as defined in claim 1, wherein the audio emitting perimeter comprises a circular array of ultrasonic emitters.

3. A device as defined in claim 1, wherein the ultrasonic emitters comprise a circular array of bimorf transducers.

4. A device as defined in claim 1, wherein the audio emitting perimeter comprises a circular configuration of ultrasonic emitter film.

15. A device as defined in claim 11, wherein emitting perimeter comprises a substantially continuous rectangular array of straight line sectors in end-to-end relationship.

16 A device as defined in claim 1, wherein the audio emitting perimeter comprises a polygon configuration of ultrasonic emitters.

17. A device as defined in claim 16, wherein the audio emitting perimeter comprises a polygon array of bimorf transducers.

18. A device as defined in claim 16, wherein the audio emitting perimeter comprises a polygon array of ultrasonic film emitter members.

19. A device as defined in claim 18, wherein the polygon array is configured in multiple segments which collectively define said audio emitting perimeter.

20. A device as defined in claim 18, wherein the polygon array is configured in multiple segments which are configured as linear sectors which collectively define larger straight line sections of the audio emitting perimeter.

21. A device as defined in claim 18, wherein the emitting perimeter is configured with a polygon geometry.

22. A device as defined in claim 18, wherein emitting perimeter comprises a substantially continuous polygon array of straight line sectors in end to end relationship.

23. A device as defined in claim 1, wherein a ratio of (i) a difference between an inner radius and an outer radius of the emitting perimeter, to (ii) the outer radius of the emitting perimeter is within a numerical range of 0.1 to 1.0.

33. A device as defined in claim 29, wherein the emitting perimeter comprises an array of piezoelectric emitters forming at least one ring of emitting material around the open space.

34. A device as defined in claim 29, wherein the emitting perimeter comprises at least one electrostatic membrane.

35. A device as defined in claim 29, wherein the emitting perimeter includes piezoelectric film material.

36. A device as defined in claim 29, wherein the emitting perimeter comprises separated emitter elements which are displaced from adjacent emitter elements along a length of the emitting perimeter, thereby spacing the emitter elements with gaps wherein no ultrasonic emissions are occurring.

37. A device as defined in claim 36, wherein the gaps are within a range of .2 to 2.0 cm.

38. A device as defined in claim 37, wherein the gaps are within the range of .5 to 1.5 cm.

39. A method for enhancing efficiency of a parametric speaker system with respect to energy output based upon emitter surface area, said method comprising the steps of:

a) forming an ultrasonic frequency emitting perimeter around an open region which is substantially void of ultrasonic emitting material; and

b) emitting ultrasonic frequency from the emitting perimeter to generate sonic or subsonic sound within surrounding air as part of a parametric speaker system.

40. A method as defined in claim 39, further comprising the step of forming the emitter material with individual emitter elements positioned along the emitting

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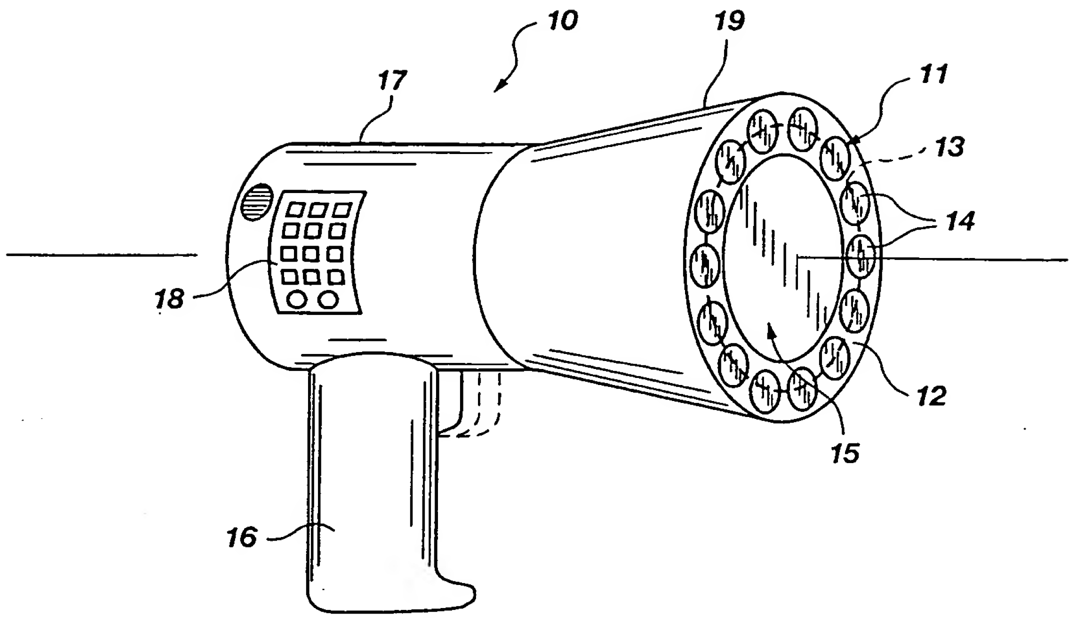

Fig. 1

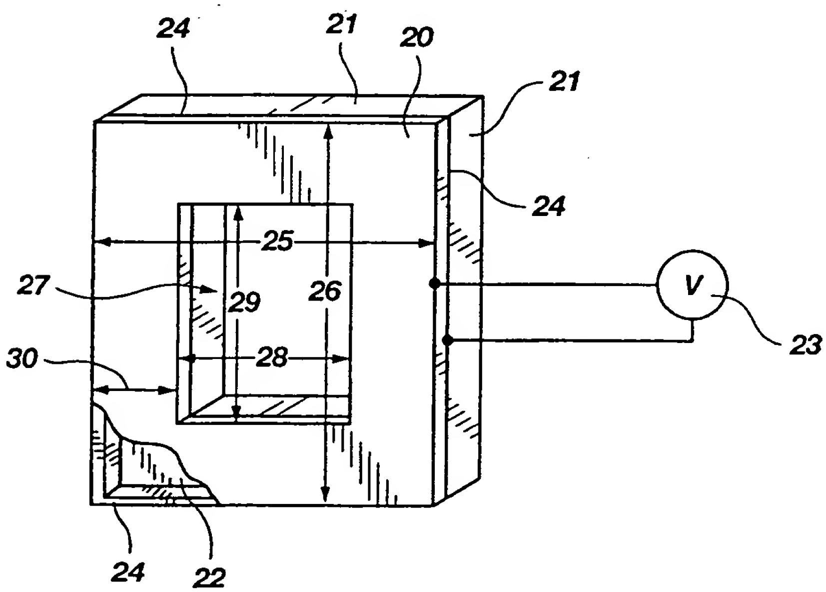

Fig. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US99/18705

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H04R 27/04, 27/00; H04B 3/00
US CL :381/75, 77, 82; 181/171, 179, 180
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 381/75, 77, 82; 181/171, 179, 180

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4,433,750 A (NEESE) 28 FEBRUARY 1984, fig. 6.	1-40
Y	JP 2-265400 A (MINAMIYAMA) 30 OCTOBER 1990, fig. 3.	1-40

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
06 JANUARY 2000	10 FEB 2000

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